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## ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

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### REVIEW: THE SPECTROSCOPY OF THE EXTREME ULTRA-VIOLET.<sup>1</sup>

This interesting book is a history of the extension of our knowledge of the solar spectrum and especially of the spectra of the chemical elements into those regions of short wave-lengths known as the ultra-violet and extreme ultra-violet.

The human eye is able to follow the solar spectrum into the violet to the vicinity of the radiations whose wave-lengths are designated as 3900 Angstroms. In 1842 BECQUEREL photographed the solar spectrum 500 units farther into the violet, to 3400 Å. A little later STOKES substituted quartz for glass in the lenses and prisms of the spectroscope, and a fluorescent screen for the Daguerreotype plate, and by these means he was able to follow the bright lines in a laboratory spectrum into the ultra-violet possibly to 1850 Å. The solar spectrum, for an observer on the Earth, seems to terminate at about 2900 Å. CORNU attributed this limitation to the absorption of our atmosphere, and there remains no doubt that this explanation is the correct one. MIETHE and LEHMANN, who made a special investigation of the subject, concluded that the limit of the solar spectrum in the ultra-violet is essentially independent of the observer's altitude above sea-level. They observed at various altitudes, from fifty meters up to 4,560 meters. Their results for the extreme altitudes were—

Berlin,            50 meters; limit of solar spectrum, 2912.6 Å  
Mt. Rosa, 4560 meters; limit of solar spectrum, 2912.1 Å

WIGAND, who photographed thru a screen (in front of the slit of his spectrograph) which was transparent to radiations in the region of 2900 Å and opaque to other radiations, reported the limit of the solar spectrum to be at 2897 Å. Why the solar spectrum is cut off so abruptly at this point is not yet fully determined; some investigators ascribe it to absorption by oxygen in the air, and others to absorption by ozone.

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<sup>1</sup> By THEODORE LYMAN, Assistant Professor of Physics in Harvard University. Octavo, pp. 135, 5 shillings net. LONGMANS, GREEN & Co., London, 1914.

The arc and spark spectra of the chemical elements are brilliant in ultra-violet, and they have been observed satisfactorily in the laboratories, by means of ordinary concave-grating spectrographs, to the vicinity of 2000 Å. Spectrographs containing glass prisms or lenses are useless in the ultra-violet, as they are opaque to the radiations. As examples: the thin cover glass of a microscopic slide, placed over the slit of a spectrograph, will limit the spectrum at about 2850 Å; and SCHOTT's uviol cover glass will place the limit near 2480 Å. Quartz prisms and lenses permit a further extension into the ultra-violet, but fluorite is much more transparent than quartz in this region. However, the atmosphere surrounding the spectrograph becomes prohibitively absorptive at about 1850 Å. SCHUMANN determined that radiations at 1940 Å may be photographed thru fourteen meters of air and a fluorite spectrograph, whereas radiations at 1750 Å may not be photographed thru one centimeter of air. This he attributed to an oxygen absorption band extending from 1900 Å to at least 1300 Å. He found, further, that in this region the gelatine on the ordinary photographic plates prevented the radiations falling upon the plates from passing on to the silver bromide grains immersed in the gelatine film.

With remarkable skill and perseverance, in the face of enormous difficulties, VICTOR SCHUMANN, of Leipzig, determined the conditions under which laboratory spectra of gases and metals could be studied in the region 1850 Å to 1230 Å, and he applied the methods with great success to the spectra of the elements, especially of hydrogen. He used fluorite for the optical parts of the spectrograph; he placed the entire spectrograph in an air-tight case and exhausted the air to a pressure of 0.5 millimeter; he used specially-prepared dry plates containing a minimum of gelatine, and differing in other respects from ordinary plates; and the apparatus was immersed in a water bath to maintain it at constant temperature. The mechanical features of the apparatus were remarkable for their refinement.

Professor LYMAN's researches of the past decade have concerned a re-survey of the SCHUMANN region of laboratory spectra and an extension of the study to a region of still

shorter wave-lengths. LYMAN's tables of wave-lengths extend to 1030 Å, and recently he has succeeded in photographing as far as 905 Å. He uses a concave Rowland speculum grating, radius of curvature 97 centimeters, ruled with nearly 600 lines to the millimeter. SCHUMANN's practices of working in vacuo and with special dry plates are of course followed. SCHUMANN's prismatic spectrum had the advantage of greater brilliancy, but LYMAN's grating spectra had the very important advantages of doing away with lenses, of having a long stretch of spectrum in accurate focus at one time, and of enabling the wave-lengths of spectrum lines to be determined very accurately. The positions of the lines were determined by the usual method of overlapping first- and second-order spectra, and likewise thru the ingenious device of two slits, separated by an interval of several centimeters, as light sources for two corresponding spectra on the same photographic plate.

The volume contains observational data of many kinds:

1. Tables of wave-lengths of bright lines in the spectra of hydrogen, nitrogen, carbon monoxide, argon, aluminum, calcium, strontium, barium, magnesium, mercury, silver, gold, cadmium, copper, tin, and zinc; principally by LYMAN, but in part by HANDKE and WOLFF.

2. On the absorption of ultra-violet light by solids, such as glass, quartz, fluorite and rock salt.

3. On the absorption of ultra-violet light by gases, such as atmospheric air, nitrogen, oxygen, ozone, carbon dioxide, carbon monoxide, helium, argon, hydrogen, and water vapor.

It is established that oxygen in the atmosphere is the chief obstacle to the passage of ultra-violet light. The part played by ozone is left in considerable doubt.

RITZ had predicted that lines in the "diffuse series" of the hydrogen spectrum should be found at 1215.6 Å and 1025.7 Å. LYMAN reports the presence of faint diffuse hydrogen lines at these points which are intensified by disruptive discharge thru the light source, whereas the other hydrogen lines in the neighborhood are weakened and blurred by this process.

Investigations on the extreme ultra-violet spectra of the elements, recently conducted by WOLFF, have found four zinc

lines, five cadmium lines, and two mercury lines precisely, we may say, where PASCHEN has predicted them.

LYMAN's recent extension of the recorded spectrum to 905 Å has been obtained chiefly by the use of a condenser and a spark gap in the circuit with the discharge tube which acts as the light source.

The bibliography of the "Spectroscopy of the Extreme Ultra-Violet" is listed extensively and very usefully in appendices. The volume closes with notes on the preparation of dry plates for photography in the SCHUMANN-LYMAN region of spectrum, and on the development of the plates.

Professor LYMAN's book can be consulted with advantage by all who are working with extreme ultra-violet radiations.

W. W. CAMPBELL.

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GIANT AND DWARF STARS AND THE ORDER OF STELLAR  
EVOLUTION.

In 1905 and in 1910, HERTZSPRUNG<sup>1</sup> pointed out the existence of two orders of luminosity among the stars of the later spectral classes and distinguished the two kinds of bodies by the names giant and dwarf, with the idea that their difference of physical constitution is at least that of size. Since then our knowledge has increased, especially as to the visual, spectroscopic, and eclipsing binaries from which many of the physical properties of stars and stellar systems can be derived. RUSSELL has collected and discussed all available data and has not only supported the hypothesis of two kinds of stars, but has formulated a hypothesis of the order of stellar development to account for the giants and dwarfs. He first announced his results in an address to the Royal Astronomical Society in London, June, 1913,<sup>2</sup> and more fully explained them in an address to Section A of the American Association for the Advancement of Science at Atlanta, December, 1913.<sup>3</sup> About this time EDINGTON<sup>4</sup> expressed the opinion that the prevailing hypothesis of the order of development from type B to type M was quite

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<sup>1</sup> *Zeitschrift für Wissenschaftliche Photographie*, **3**, 442, 1905; *Astron. Nach.*, **185**, 90, 1910.

<sup>2</sup> *The Observatory*, **36**, 324, 1913.

<sup>3</sup> *Nature*, **93**, 227, 252, 281, 1914; *Popular Astronomy*, **22**, 275, 331, 1914.

<sup>4</sup> *The Observatory*, **36**, 470, 1913.

well supported by the relation of increasing periods in binary systems and of increasing average peculiar motion of stars to the order B to M. RUSSELL<sup>5</sup> responded to this opinion with a statement of objections to the present order B to M. These objections are briefly as follows:—

1. It is generally supposed that the stellar surface temperature and luminosity decrease together from class B to class M. But it is found that certain stars of all classes are of similar high luminosity.

2. It is generally accepted that class B stars have the highest temperatures, so that many intermediate stages of increasing temperature between diffused primordial matter and class B stars are to be expected. But there are too few in the sequence O, B, . . . M.

3. The densities of class B stars are higher than expected for earliest stages, in fact higher than that of the Sun expanded only four-fold. In cooling from type B to type M they could not decrease in density, or expand, to the state of certain later type stars of extremely low density.

4. Class B stars are more massive than other classes; but it is not probable that mass diminishes with the transition from type B to type M.

5. The observed increase of period of spectroscopic binaries with advancing type is strong evidence against the order B to M, since in the theory of tidal evolution, there is a limit to the separation and the period. Long periods cannot evolve from short periods. Short-period binaries formed in early stages would remain relatively short; but such are absent in classes K and M.

6. The increase of average peculiar motion of the several spectral classes is unexplainable by the order B to M; but it is well explained by the hypothesis that velocity is greater in proportion as mass is less.

RUSSELL has drawn his data from four groups of stars: first, 300 stars whose parallaxes have been more or less accurately determined; second, 150 members of the moving-clusters in *Taurus*, *Ursa Major*, *Cygnus*, *Scorpius*, whose parallaxes are known; third, 550 visual binaries whose hypo-

<sup>5</sup> *The Observatory*, **37**, 171, 1914.

thetical parallaxes and absolute magnitudes are derived by the statistical method; and 90 eclipsing variables for which RUSSELL and SHAPLEY have derived densities and hypothetical luminosities. Plots of the luminosities against the spectral sequence B, A, F, G, K, M, for each of the four groups of stars show similar results: namely, that the early class stars are the brightest; that the later class stars are both bright and faint, while class M entirely lacks stars of intermediate brightness of the order of that of the Sun; and finally that the range of luminosity increases with advancing type to the extent of a million-fold. The data of visual and spectroscopic binaries show a range of mass of fifty-fold, of mean mass only thirty-fold, and of density a great range. From the data pertaining to eclipsing variables it is evident that surface brightness diminishes with advancing spectral type, and that density has a tendency to increase among the less luminous stars, while among the most luminous stars density diminishes enormously—to one-millionth that of the Sun. The range is more than a million-fold.

Luminosity is affected by at least the three factors of mass, surface brightness, and density. The facts presented above allow the following inferences: The observed range of mass is too small to account for the great range of luminosity; if surface brightness is less for the later than for the early type stars, that factor cannot cause the great luminosity of some of the later type stars; since great and sufficient range of density is observed, density may well be the factor producing the great range of luminosity.

Two points, RUSSELL thinks, may now be granted at least provisionally; namely, that these results or inferences represent stars in general and that in accordance with the LANE-RITTER law for gaseous bodies the stars under the action of gravitation condense and increase in density continuously, rise in temperature to a maximum and then gradually cool. Upon these points RUSSELL bases the following hypothesis to account for the two orders of luminosity, using the terms giant and dwarf for the stars of great and of small luminosity, respectively:—

The spectral class M represents the earliest as well as the latest type of spectrum; when earliest, the star is of huge proportions with extremely low density and just beginning to rise in temperature, but when latest the star has reached its last stage of temperature and luminosity and nearly its greatest density. The classes K, G, F, A, represent intermediate stages both of rising and falling temperature. The giants and dwarfs are more and more nearly of the same order of luminosity until in class B they are undifferentiated. Class B represents the last type of spectrum and the highest stage of temperature and that of critical density at which a contracting body begins to diminish its heating and radiating power. The order of transition will then be M, K, G, F, A, B, A, F, G, K, M.

In support and explanation of the hypothesis he mentions the following points: The critical density corresponding to the maximum temperature was estimated by Lord KELVIN to be about one-tenth the density of water. Eclipsing binaries of classes B and A are found to have an average density about one-sixth that of water, a very close approach to the estimated value. The similar degree of luminosity among the giants of all classes may be due to the counteractive effects of increase of density and of surface brightness. The apparent scarcity of intermediate stages of increasing temperature between diffused primordial matter and class B stars in the present sequence of types is obviated by the proposed sequence and it is argued that it is more probable that the giant stars represent the early stages than that these stages have ceased to exist. The proposed order accounts for the relatively high density of class B stars and obviates the anomaly of class B stars becoming giants of type M. Presumably only the greater masses may attain the highest temperatures. This is substantiated by the well-established facts that class B stars are the most massive and have the highest temperatures. The smaller masses may not attain the highest temperature nor pass thru the entire sequence of spectral types. Many stars may have their turning points at K or G or F. The greater numbers in successive classes from B to M would probably cause a diminishing value of average mass and account for the fact that class

B stars are the most massive. The observed distribution of spectroscopic binaries and their periods may be explained thus: The formation of binaries will occur more frequently during the middle stages of condensation than in the earliest stages, so that binaries will be more numerous, and younger, and of shorter period, among stars in the middle stages of transition. Class B stars actually show the greater number of binaries and the shorter periods. The explanation of the increase of mean peculiar velocity of the classes from B to M upon the hypothesis that velocity is greater in proportion as mass is less, in connection with the proposed order of spectral transition, is substantiated by the observed diminishing increment of the velocity from class to class; in other words, the average of the mean peculiar velocities of the giants and dwarfs in those classes in which they are separated is very nearly of the same value.

The new hypothesis takes into account quite satisfactorily many hitherto unexplained points. But one very important point is untouched. Two incontrovertible facts are before us which must be taken into account in an acceptable hypothesis of stellar evolution. First, nebulosity is found associated only with spectral types B and O. Second, spectral type M, whether pertaining to the giant or dwarf character of star, is not known to be connected with nebulosity. The new hypothesis has searched for early stages between primordial matter, presumably nebulosity, and class B stars, but it has not found stages previous to its own earliest forms, the giants of class M. If the M type giants transform to the B type, a cause must be discovered either for the production of nebulosity about them in the latter stage, or for their introduction into nebulosity. Since the giants share, in part at least, the peculiar velocity of the later class stars, the loss of this motion would have to be accounted for upon their attainment of spectral type B. A crucial point is, What part does nebulosity play in the physical transition of stars, and it may be asked, whether nebulosity may or may not produce particular spectral effects or types, irrespective of the effects proceeding out of the physical transition in accordance with the LANE-RITTER law.